

Effect of low coconut fiber concentration on the mechanical and physical properties of load-bearing concrete hollow blocks

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Abstract

This study examined the effects of low coconut fiber concentrations on the mechanical and physical properties of load-bearing Concrete Hollow Blocks (CHBs). It evaluated the compressive strength, water absorption, and density of 5-inch Coconut Fiber-Reinforced Concrete Hollow Blocks (CFRCHBs) with coconut fiber concentrations of 0.1%, 0.3%, and 0.5% by mass of cement, compared to conventional CHBs used as the control. The relationship between curing time and fiber percentage was also analyzed through 7-day, 14-day, and 28-day curing periods, along with the production cost per square area of the CFRCHBs. An experimental research design was implemented following ASTM C140 standards and the National Structural Code of the Philippines (NSCP) for load-bearing masonry units. Fifty-four (54) CHB specimens were produced using a 1:7 cement-to-crushed sand mix ratio and a water-cement ratio of 0.51. Coconut fibers from mature husks were treated by boiling, sun-drying, and cutting into 6 cm lengths before mixing. Compressive strength testing was conducted with a Universal Testing Machine (UTM), while density and water absorption tests adhered to ASTM procedures. Two-way ANOVA was used to determine the significance of curing time and fiber concentration on the measured properties. Results indicated that longer curing time significantly increased compressive strength and decreased water absorption in all samples. Among the mixtures tested, the 0.3% coconut fiber concentration provided the most balanced performance in strength, density, and water absorption, suggesting it as the optimal fiber content for load-bearing CHBs. The study also underscored the sustainability of CFRCHBs by utilizing agricultural waste and demonstrated their potential for residential and single-storey detached housing units. Overall, low concentrations of treated coconut fiber enhanced selected CHB properties while promoting sustainable construction practices.

Keywords: coconut fiber-reinforced concrete hollow blocks, compressive strength, water absorption, load-bearing concrete hollow blocks, sustainable construction

Introduction

Concrete Hollow Block (CHB) is a prominent material used for walling purposes in buildings and infrastructures either for load-bearing, and non-load bearing. The CHB allows for thinner walls, resulting in more floor space because the air space in the block accounts for 25% of the total of the block. Moreover, it is still among the earliest building materials in use today (Yang et al., 2019) [1]. Additionally, it is a frequent and regular choice due to its benefits, such as its simplicity as a building element, significant strength comparable to bricks, and adaptability to achieving various architectural formations.

CHB is most effective in load-bearing structures, where it can provide load support, space division, fire and weather protection, and thermal and acoustic insulation, all of which must be separately accounted for in a framed building. Kushwaha (2023) [2] made a list of some of the advantages that CHBs have to offer, and this includes reduced weight due to their hollow structure, which then makes handling more convenient than their dense counterparts. Commonly used for wall systems, this material aids in regulating the internal temperature of a building, as well as the sound that gets transmitted from one side of the wall to the other. CHBs are also regarded as more cost-effective than other materials of the same purpose. Moreover, the cavities of CHBs allow for easy reinforcement installation, therefore, also putting an ease to the construction process. Despite these benefits, the utilization of CHBs also comes with its own risks. The same author

claimed that the compressive strength of CHBs may be lower than the solid ones, and this is a massive concern for load-bearing applications. Water absorption can also be a problem to be dealt with in using CHBs because their durability would decrease given that no waterproofing or sealing process had been done. In order to achieve the desired structural integrity of a wall built with CHBs, the correct placement of reinforcement shall be ensured to be accurate and this makes the construction process a bit more complex. However, cracking in walls made from hollow blocks is a common issue caused by several factors, including thermal expansion, material shrinkage, construction quality, and deficiencies in design. Researchers have tried strategies to mitigate this problem, focusing on the improvement of the materials, reinforcement plans, and retrofitting solutions.

According to Martinelli et al. (2023) [3], the use of plant fibers in cementitious composites has been gaining prominence with the need for more sustainable construction materials. It occurs due to the advantages natural fibers provide to these composites, such as the reduction of density, fragmentation, and propagation of cracks in concrete. The properties of natural fibers for their application in civil engineering remain a topic of interest for a wide range of studies. Natural fibers are considered as the prospective material to be used as reinforcement materials in composite products (Bui et al., 2020) [4]. Although weak bonding between fibers and the matrix and their relatively significant moisture absorption are considered as the main drawbacks of natural fibers in composite products. Thus, to modify the surface properties of fibers for improving their adhesion with the matrix, treatment of fibers is highly considered. Some of the techniques include physical and chemical methods to treat fibers before application.

Recent research including Izquierdo et al. (2017) [5] investigated how sisal fibers affected the mechanical behaviour of individual CHBs, along with prisms and wallettes that are made of such. The study mentioned that sisal fibers possess high tensile strength, toughness, and abrasion resistance. The researchers further mentioned that such plant fiber aids in reducing the chances of cracks to spread all over the concrete's surface by controlling their opening. Moreover, the study also explained that cement-based materials that had been reinforced with long, unidirectional sisal fibers can withstand tension and bending. All of these reflected in the results of the study where it showed that incorporating sisal fibers to the concrete mixture increased the ductility of CHBs even though it failed to enhance their compressive strength and elastic modulus. These conclusions, however, are limited to the utilization of raw and untreated sisal fibers, which means that the results may have been different had the fibers been treated in a way.

Meanwhile, in the Philippines, a country that produces nearly 5 million tons of organic waste each year (NaturLoop, 2022) [6], Villar SIPAG Foundation focuses on converting coconut husk waste into "coconets". These nets are employed as riprap material in construction (Manila Bulletin, 2020) [7]. On the same note, NaturLoop is leading the creation of a pilot Consolidation Centre (CC) that will convert coconut waste into Cocoboards. The project seeks to optimize the entire production process from collecting coconut husks to manufacturing building panels which aims in offering an eco-friendly alternative to traditional wood materials (NaturLoop, 2022) [6]. Recent studies highlight that coconut coir fibers, obtained from coconut husks, can be used to enhance the structural properties of concrete blocks, making them stronger and more resilient. Both the enhancement of CHBs with coconut fiber and the production of "coconets" and "cocoboards" from coconut husks showcase how waste can become an economic and environmental asset. Moreover, the research on CHBs reinforced with coconut coir is closely tied to the waste management efforts of the Villar SIPAG foundation and NaturLoop in the Philippines.

While coconut fibers are already explored in the construction industry, they find applications in cement mortar by enhancing ductility and crack resistance when paired with additives like silica fume or metakaolin (Nawab et al., 2023) [8]. They improve flexural strength in masonry plasters and offer superior impact resistance in cement boards compared to traditional CHBs. In adobe blocks, coconut fibers boost compressive strength and thermal insulation (Sanou et al., 2024) [9]. In reinforced concrete beams, they mitigate cracking under bending and shear (Kazi et al., 2024) [10]; and in roads, they stabilize bases alongside coconut shells.

Coconut fibers work well in many construction components like mortars, boards, masonry blocks, beams, and roads, where they boost strength and eco-friendliness. Yet, their use in load-bearing CHBs is limited, opening a gap for this study to cover. The study of Baguhin and Cabahug (2019) [11] entitled "Investigation

on Load-Bearing Concrete Hollow Block Reinforced with Coconut Coir Fiber” stated that incorporating 1% and 2% pre-treated coconut fiber to the CHB mixture, utilizing fiber lengths of 6 and 4.5 cm, respectively, provides compressive strength exceeding the control. However, the study only tested for the CHB’s compressive strength after curing for 28 days only. The present research incorporates additional tests, such as water absorption, to address variations that may indicate deleterious materials in the concrete mix, poor mixing quality, or inadequate compaction—all of which can compromise compressive strength and durability. Low water absorption often indicates overly dense or well-compacted mixes with minimal voids, suggesting good durability and strength.

Moreover, in the study of Dela Cruz et al. (2020) [12] determined the compressive strength, water absorption rate, workability, and economic benefit of using coconut shells and coir fiber in place of some of the coarse aggregate in CHB. While the findings demonstrate the feasibility of using coconut shell and coir fiber, an agricultural waste, as a partial substitute for coarse aggregate in the production of CHBs, the study focused more on non-load bearing CHBs. Similarly, Ganiron et al. (2017) [13] stated that coconut shells and fibers are applicable as a partial substitute for coarse aggregates of CHBs, and that the non-load bearing CHBs tested on the study gained higher compressive strength compared to the conventional CHBs after 28 days of curing. Incorporating 7-day and 14-day compressive strength tests for CHBs offers early insights into mix quality and curing effectiveness. These tests typically show blocks achieving about 65% of ultimate strength at 7 days and roughly 90% at 14 days, verifying uniform hydration and reliably predicting 28-day performance.

Samson and Gatdula (2025) [14] used coconut coir as a partial replacement for sand in CHB, which also served as an additional fiber reinforcement. On the other hand, Rumbayan et al. (2020) [15] innovated coir-integrated concrete blocks to achieve a lightweight construction material. The former used a cement to sand ratio of 1:12, while the latter used 1:5; both resulted in the compressive strength of their Coconut Fiber-Reinforced Concrete Hollow Block (CFRCHB) specimens to be lower than the control. With this, Rumbayan recommended that their study be used as non-load bearing CHBs. These results then call for the need of choker aggregates in the concrete mix to create load-bearing versions of CFRCHBs.

Materials and Methods

Research Design

An experimental research design was employed to conduct the study, focusing on assessing the compressive strength, water absorption, and density of CHBs integrated with 0.1%, 0.3%, and 0.5% coconut fiber concentration. The exploration of the use of natural fibers as reinforcement for construction materials such as CHB is an innovative medium. Along with the determination of the optimum concentration of coconut fibers in CHBs, the research also compared the by-products with a control sample, specifically 5-inch load-bearing CHBs with a primary composition of 1 part Portland cement, 7 parts crushed sand, and water. The samples followed a standard measurement of 8 in. height by 16 in. length by 5 in. thickness with varying fiber concentration. The researchers produced a total of twenty-seven (27) CFRCHB: specifically, the first nine (9) samples were integrated with a 0.1% coconut fiber concentration, the next nine (9) specimens with 0.3% coconut fiber concentration, and the last nine (9) specimens with a coconut fiber concentration of 0.5% for testing of compressive strength. A total of eighteen (18) control specimens were also created following the conventional composition of CHBs, as well as its dimensions. Specifically, the three (3) control samples were produced for each curing time for water absorption testing. The other nine (9) remaining CFRCHB samples were produced in line with the optimum fiber concentration determined from the highest compressive strength. The researchers used a CHB molder, specifically for a standard 5” size with face shell thickness of 25 mm, and web thickness: 25 mm for webs, and 188 mm equivalent web thickness (mm/linear m) as specified under DPWH Standard Specification for Item 1046 - Masonry Works. The researchers had based on the standards set by the American Society for Testing and Materials (ASTM) in order to assess the compressive strength, density, and water absorption of the samples, and ensure reliability and comparability with other studies.

Materials Used

The researchers gathered the coconut husks in the City of San Fernando, La Union which served as the medium to extract coconut fibers from. Portland cement and crushed sand were purchased from BZA Apil Aggregates. The CHB samples of the different ratios of coconut fiber and the control sample were molded in coordination with the same aforementioned construction supplier for a better form. Materials such as water, coconut fibers, Portland cement, and crushed sand, were gathered for the concrete mixture.

Sample Preparation

The coconut fibers were treated by boiling them for two hours, after which they were sun-dried. Once fully dried, the fibers were cut into 6 cm lengths and measured with a conventional ruler to ensure uniformity. The concrete was then mixed with a ratio of 1:7 (cement:crushed sand) with a water-cement ratio of 0.51. Coconut fibers were added in varying percentages of 0%, 0.1%, 0.3%, and 0.5% by mass of cement, where 0% served as the control. The concrete mixture was poured and compacted into the molds. After compaction, the samples were carefully removed from the molds and cured for 7, 14, and 28 days through water sprinkling.

Experimental Procedure

Upon completion of each curing period, 12 samples from each curing period (7, 14, and 28 days) underwent compressive strength tests and density tests to assess the structural performance and compactness of the CFRCHBs. The remaining 6 samples from each curing period were used for water absorption testing to evaluate the material's permeability and durability. The water absorption samples were oven-dried for 24 hours at a temperature between 100–115 °C. After oven drying, the samples were weighed to obtain their oven-dried mass, then submerged in water for 24 hours to obtain the immersed mass, and then after submersion, the samples were weighed again to record their wet masses after wiping off surface moisture. The results from these tests were analyzed and tabulated to facilitate comparison between the control samples and the CFRCHBs, thereby determining the influence of coconut fiber reinforcement on the mechanical and physical properties of the CHBs.

Data Gathering Procedure

The study obtained measurements for compressive strength, water absorption, and density of the specimens. The results were evaluated using two-way ANOVA. Through this method, the effects of fiber content and curing duration on compressive strength, density, and water absorption were examined, as well as the interaction between the two independent variables. The compressive strength for each sample was obtained by dividing the maximum load it withstood under testing by the surface area in direct contact with the loading plate. The compressive strength was then analyzed and compared across varying coconut fiber contents of 0%, 0.1%, 0.3%, and 0.5%, as well as different curing periods of 7, 14, and 28 days, to conduct a comparative evaluation and identify the optimal fiber percentage that enhances the performance of CFRCHBs.

Treatment of Data

The compressive strength of the control specimens and CFRCHB was computed using the equation:

$$\text{Compressive strength } f_c' = P / A$$

Equation 1

The density of the control specimens and CFRCHB was computed using the equation:

$$\text{Density } \rho = m / V$$

Equation 2

The water absorption of the control specimen and CFRCHB was computed using the equation:

$$\text{Water Absorption, WA (\%)} = ((W2 - W1) / W1) \times 100\%$$

Equation 3

Two-way ANOVA was used to analyze the results and determine the significance of differences between the CFRCHB groups and the control specimens. It determined how fiber concentration and curing time would affect the compressive strength, density, and water absorption of CHB, and found a possible relationship between these two independent factors.

Results and Discussion

Compressive Strength Test

Table 1. Compressive Strength of CHB specimens

Sample identification	No.	7 days	Mean	14 days	Mean	28 days	Mean
CONTROL CHB	1	2.136		4.341		6.382	
	2	2.923	2.643	5.987	4.989	7.246	6.122
	3	2.871		4.639		4.740	
0.1% CFRCHB	1	2.643		5.637		5.146	
	2	3.886	3.029	5.602	5.794	4.606	5.773
	3	2.556		6.145		7.568	
0.3% CFRCHB	1	4.376		4.587		6.788	
	2	3.904	4.394	7.160	5.660	6.169	6.561
	3	4.902		5.234		6.725	
0.5% CFRCHB	1	2.538		5.287		6.694	
	2	2.959	2.696	5.777	5.689	4.663	6.113
	3	2.591		6.005		6.981	

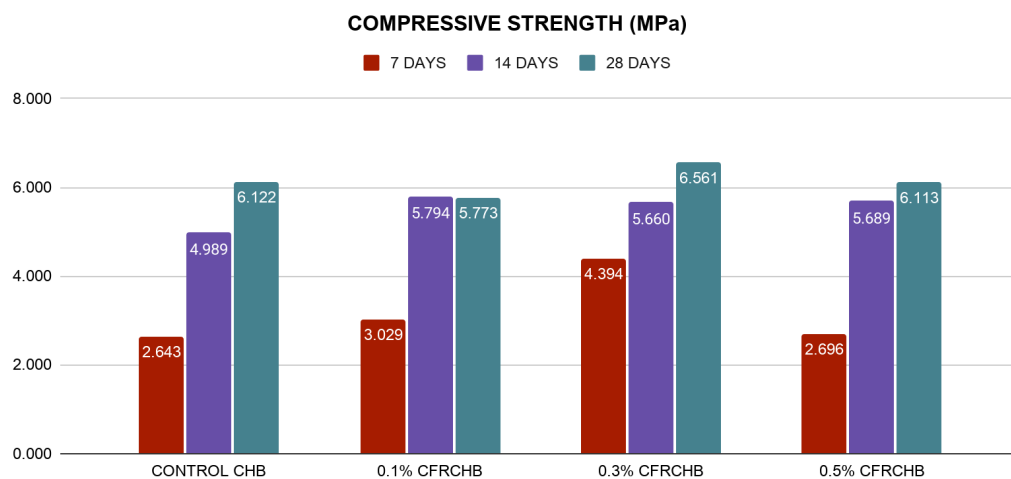


Figure 1. Compressive Strength of CHB specimens

The compressive strength of CFRCHB mixture proportions with 7, 14, and 28 days is shown in Figure 1. The highest mean compressive strength among the four CHBs is the 0.3% CFRCHB having a compressive strength of 4.394 MPa at 7 days, 5.660 MPa at 14 days, and 6.561 MPa while the lowest compressive strength is the control with 2.643 MPa at 7 days, 4.989 MPa at 14 days, and 6.122 MPa at 28 days of curing. The CFRCHB with 0.1% and 0.5% also exhibited improved compressive strength compared to the control, particularly at later curing ages. At 7 days, both mixes showed modest gains, with 0.1% at 3.029 MPa and 0.5% at 2.696 MPa. By 14 days, their strengths increased to 5.794 MPa and 5.689 MPa, respectively, indicating significant development in structural capacity. At 28 days, the 0.5% CFRCHB reached 6.113

MPa, closely approaching the control, while the 0.1% CFRCHB recorded 5.773 MPa, slightly lower than the other mixtures.

Overall, all CFRCHB mixtures demonstrated a consistent increase in compressive strength with curing time. However, the 0.3% CFRCHB mixture consistently outperformed the other proportions at all curing stages, suggesting that this percentage provides the most optimal balance for enhancing compressive strength.

Density Determination and Interpretation

Table 2. Density of CHB specimens

Sample identification	No.	7 days (kg/m ³)	Mean	14 days (kg/m ³)	Mean	28 days (kg/m ³)	Mean
CONTROL CHB	1	2052.724		2096.661		2158.172	
	2	2001.757	2055.653	2117.750	2113.064	2100.176	2127.709
	3	2112.478		2124.780		2124.780	
0.1% CFRCHB	1	1996.485		2131.810		2103.691	
	2	2068.541	2036.321	2123.023	2112.478	2144.112	2135.325
	3	2043.937		2082.601		2158.172	
0.3% CFRCHB	1	2149.385		2124.780		2096.661	
	2	2049.209	2120.680	2070.299	2100.762	2147.627	2135.911
	3	2163.445		2107.206		2163.445	
0.5% CFRCHB	1	2033.392		2114.236		2170.475	
	2	2087.873	2030.463	2070.299	2108.963	2094.903	2140.598
	3	1970.123		2142.355		2156.415	

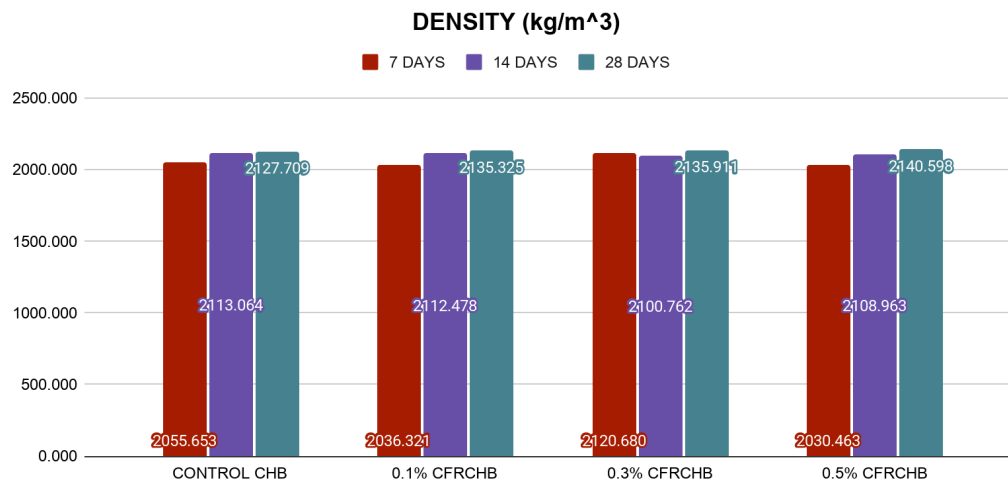


Figure 2. Density of CHB specimens

CHBs are generally expected to have a density of about 2,000–2,400 kg/m³ for normal-weight CHB. The results show that both mix, control and CFRCHB fall within this acceptable range at all curing ages, indicating compliance with standard requirements. At 7 days, densities are just above 2,000 kg/m³, while at 14 and 28 days they increase to around 2,100–2,140 kg/m³, reflecting improved compaction and continued hydration. The addition of CFRCHB does not push the density outside the standard limits but instead maintains or slightly enhances it, with the 0.5% CFRCHB mix reaching the upper end among the samples. Overall, all mixes are within the DPWH-prescribed density range, confirming that incorporating coconut

fibers does not adversely affect the classification of the blocks as normal-weight CHB and remains suitable for construction use.

Water Absorption Test Results and Interpretation

Table 3. Water Absorption Capacity of CHB specimens

Sample identification	No.	7 days (%)	Mean	14 days (%)	Mean	28 days (%)	Mean
CONTROL CHB	1	7.05		8.01		8.84	
	2	6.73	6.51	7.43	7.76	8.64	8.75
	3	5.76		7.83		8.77	
0.3% CFRCHB	1	7.67		4.51		6.04	
	2	6.52	7.46	4.31	4.34	5.91	6.05
	3	8.18		4.19		6.19	

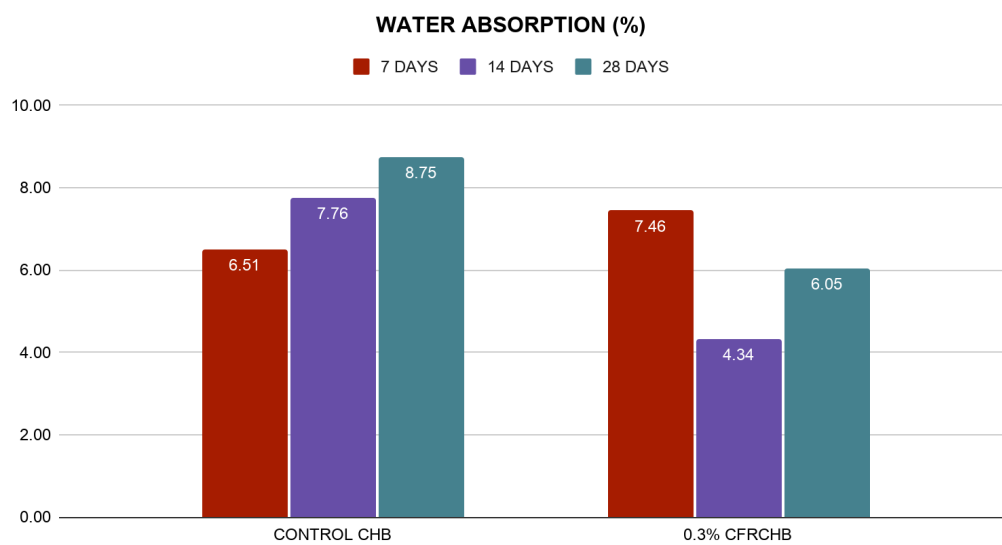


Figure 3. Water Absorption of CHB specimens

The graph shows the mean water absorption of the control CHB and CFRCHB samples containing 0.3% coconut fibers with curing periods of 7, 14, and 28 days. The data for the control specimens show linearity as the water absorption increases with the number of curing days. This relationship is not exhibited by the data for the 0.3% CFRCHB as the water absorption drops at 14 days, then goes back up at 28. The former group of data contains the sample with the highest water absorption, cured at 28 days with the value of 8.75, while the latter possesses the one with the lowest value - a 4.34 cured at 14 days. It can also be seen that the mean water absorption values of 0.3% CFRCHB are generally lower than those of the control CHBs - indicating that the specimens are more dense and resistant to penetration of moisture, making them more durable than the control group.

Data Analysis

Table 4. Null and Alternative Hypotheses

Hypothesis	Statement
h0	There is no significant difference in the dependent variable values of the samples with different levels of independent variables.
h1	There is a significant difference in the dependent variable

Hypothesis	Statement
	values of the samples with different levels of independent variables.

Table 5. Rejecting / Accepting Null Hypothesis

Conditions	Interpretation
$F > F_{\text{crit}}$	with significant difference
$F < F_{\text{crit}}$	no significant difference
Result	$F > F_{\text{crit}}$; therefore, reject null hypothesis (H_0)

One-way ANOVA**Compressive Strength****Table 6(a).** One-Way Analysis of Variance of Compressive Strength (7 days)

Groups	Count	Sum	Average	Variance
0	3	7.930	2.643	0.194
0.001	3	9.085	3.028	0.554
0.003	3	13.182	4.394	0.249
0.005	3	8.088	2.696	0.053

Table 6(b). One-Way Analysis of Variance of Compressive Strength (7 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6.056	3	2.019	7.696	0.00961	4.066
Within Groups	2.098	8	0.262			
Total	8.154	11				

Table 7(a). One-Way Analysis of Variance of Compressive Strength (14 days)

Groups	Count	Sum	Average	Variance
0	3	14.967	4.989	0.769
0.001	3	17.384	5.795	0.092
0.003	3	16.981	5.660	1.791
0.005	3	17.069	5.690	0.135

Table 7(b). One-Way Analysis of Variance of Compressive Strength (14 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.215	3	0.405	0.581	0.64362	4.066
Within Groups	5.575	8	0.697			
Total	6.791	11				

Table 8(a). One-Way Analysis of Variance of Compressive Strength (28 days)

Groups	Count	Sum	Average	Variance
0	3	18.368	6.123	1.620
0.001	3	17.320	5.773	2.489
0.003	3	19.682	6.561	0.116
0.005	3	18.338	6.113	1.597

Table 8(b). One-Way Analysis of Variance of Compressive Strength (28 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.937	3	0.312	0.215	0.88351	4.066
Within Groups	11.644	8	1.455			
Total	12.581	11				

Table 8(b) shows that the F-value and F-critical value of the 7-day cured samples for compressive strength test are 7.696 and 4.066, respectively. The former is larger than the latter; therefore, indicating that the different levels of fiber percentage impose a significant difference towards the said dependent variable. In the case of the 14-day cured samples under the same property, the F-value (0.581) is lower than the F-critical value (4.066) which then means that the fiber percentages do not affect the compressive strength. This is the same for the 28-day cured specimens with an F-value of 0.215 and F-critical value of 4.066.

Water Absorption

Table 9(a). One-Way Analysis of Variance of Water Absorption (7 days)

Groups	Count	Sum	Average	Variance
0	3	19.540	6.513	0.453
0.003	3	22.365	7.455	0.719

Table 9(b). One-Way Analysis of Variance of Water Absorption (7 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.330	1	1.330	2.270	0.20639	7.709
Within Groups	2.345	4	0.586			
Total	3.675	5				

Table 10(a). One-Way Analysis of Variance of Water Absorption (14 days)

Groups	Count	Sum	Average	Variance
0	3	23.277	7.759	0.089
0.003	3	13.017	4.339	0.025

Table 10(b). One-Way Analysis of Variance of Water Absorption (14 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	17.546	1	17.546	306.8	0.00006	7.709
Within Groups	0.229	4	0.057			
Total	17.775	5				

Table 11(a). One-Way Analysis of Variance of Water Absorption (28 days)

Groups	Count	Sum	Average	Variance
0	3	26.248	8.749	0.011
0.003	3	13.138	6.046	0.020

Table 11(b). One-Way Analysis of Variance of Water Absorption (28 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10.961	1	10.961	705.8	0.00001	7.709
Within Groups	0.062	4	0.016			
Total	11.023	5				

It can be seen that the F-value and F-critical value of the 7-day cured samples for water absorption test are 2.270 and 7.709, respectively. The former is lower than the latter; therefore, indicating that the different levels of fiber percentage does not significantly impact water absorption of CFRCHBs. In the case of the 14-day cured samples under the same property, the F-value (306.8) is higher than the F-critical value (7.709) which then means that the fiber percentages do affect the said dependent variable. This is the same for the 28-day cured specimens with an F-value of 705.8 and F-critical value of 7.709.

Density

Table 12(a). One-Way Analysis of Variance of Density (7 days)

Groups	Count	Sum	Average	Variance
0	3	6166.960	2055.653	3071.196
0.001	3	6108.963	2036.321	1341.525
0.003	3	6362.039	2120.680	3880.434
0.005	3	6091.388	2030.463	3472.726

Table 12(b). One-Way Analysis of Variance of Density (7 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15394.8	3	5131.6	1.745	0.2351	4.066
Within Groups	23531.7	8	2941.4			
Total	38926.6	11				

Table 13(a). One-Way Analysis of Variance of Density (14 days)

Groups	Count	Sum	Average	Variance
0	3	6339.192	2113.064	214.150
0.001	3	6337.434	2112.478	688.780
0.003	3	6302.285	2100.762	773.204
0.005	3	6326.889	2108.963	1318.874

Table 13(b). One-Way Analysis of Variance of Density (14 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	289.051	3	96.35	0.129	0.9403	4.066
Within Groups	5990.015	8	748.7			
Total	6279.066	11				

Table 14(a). One-Way Analysis of Variance of Density (28 days)

Groups	Count	Sum	Average	Variance
0	3	6383.128	2127.709	847.333
0.001	3	6405.975	2135.325	799.973
0.003	3	6407.733	2135.911	1217.977
0.005	3	6421.793	2140.598	1615.389

Table 14(b). One-Way Analysis of Variance of Density (28 days)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	256.105	3	85.368	0.07	0.9710	4.066
Within Groups	8961.343	8	1120.1			
Total	9217.447	11				

Under the density property, the F-value of the specimens cured for 7 days is 1.745, which is lower than its F-critical value, 4.066, indicating that the fiber percentages do not have a significant impact towards density. For the ones cured for 14 days, the F- and F-critical values are 0.129 and 4.066, respectively. Again, the former is lower than the latter which means that the changes in the independent variable do not do much to the dependent variable. This is also true for the specimens cured for 28 days with its F-value being 0.07, and F-critical value of 4.066.

Two-way ANOVA

Compressive Strength

Table 15(a). Two-way Analysis of Variance of Compressive Strength

Summary	7 days	14 days	28 days	Total
0				
Count	3	3	3	9
Sum	7.930	14.967	18.368	41.265
Average	2.643	4.989	6.123	4.585
Variance	0.194	0.769	1.620	3.007
0.001				
Count	3	3	3	9
Sum	9.085	17.384	17.320	43.789
Average	3.028	5.795	5.773	4.865
Variance	0.554	0.092	2.489	2.682
0.003				
Count	3	3	3	9
Sum	13.182	16.981	19.682	49.845
Average	4.394	5.660	6.561	5.538
Variance	0.249	1.791	0.116	1.428
0.005				
Count	3	3	3	9
Sum	8.088	17.069	18.338	43.495
Average	2.696	5.690	6.113	4.833
Variance	0.053	0.135	1.597	3.048
Total				
Count	12	12	12	
Sum	38.285	66.401	73.708	
Average	3.190	5.533	6.142	4.955
Variance	0.741	0.617	1.144	

Table 15(b). Two-way Analysis of Variance of Compressive Strength

Source of Variation	SS	df	MS	F	P-value	F crit
Fiber Percentage	4.501	3	1.500	1.864	0.162638	3.009
Curing Period	58.297	2	29.148	36.215	0.000000056490	3.403
Interaction	3.707	6	0.618	0.768	0.602582	2.508
Within	19.317	24	0.805			
Total	85.823	35				

Water Absorption

Table 16(a). Two-way Analysis of Variance of Water Absorption

Fiber percentage	7 days	14 days	28 days
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Fiber percentage	7 days	14 days	28 days
0%	7.05	8.01	8.84
	6.73	7.43	8.64
	5.76	7.83	8.77
0.30%	7.67	4.51	6.04
	6.52	4.31	5.91
	8.18	4.19	6.19

Table 16(b). Two-way Analysis of Variance of Water Absorption

Source of Variation	SS	df	MS	F	P-value	F crit
Fiber Percentage	13.416	1	13.416	61.054	0.0000047817739	4.747
Curing Period	5.757	2	2.878	13.098	0.000961	3.885
Interaction	16.425	2	8.213	37.373	0.000007	3.885
Within	2.637	12	0.220			
Total	38.235	17				

Density**Table 17(a).** Two-way Analysis of Variance of Density

Summary	7 days	14 days	28 days	Total
0				
Count	3	3	3	9
Sum	6166.959	6339.191	6383.128	18889.278
Average	2055.653	2113.064	2127.709	2098.809
Variance	3071.219	214.141	847.320	2120.994
0.001				
Count	3	3	3	9
Sum	6108.963	6337.434	6405.975	18852.372
Average	2036.321	2112.478	2135.325	2094.708
Variance	1341.519	688.779	799.953	2723.021
0.003				
Count	3	3	3	9
Sum	6362.039	6302.285	6407.733	19072.057
Average	2120.680	2100.762	2135.911	2119.117
Variance	3880.463	773.192	1217.974	1700.932
0.005				
Count	3	3	3	9
Sum	6091.388	6326.890	6421.793	18840.071
Average	2030.463	2108.963	2140.598	2093.341
Variance	3472.701	1318.868	1615.432	4013.348
Total				
Count	12	12	12	
Sum	24729.349	25305.800	25618.629	
Average	2060.779	2108.817	2134.886	2101.494
Variance	3538.793	570.818	837.950	

Table 17(b). Two-way Analysis of Variance of Density

Source of Variation	SS	df	MS	F	P-value	F crit
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Source of Variation	SS	df	MS	F	P-value	F crit
Fiber Percentage	3872.830	3	1290.943	0.80	0.50337	3.009
Curing Period	33916.018	2	16958.009	10.5	0.00050	3.403
Interaction	12067.243	6	2011.207	1.25	0.31486	2.508
Within	38483.105	24	1603.463			
Total	88339.195	35				

Under the two-way ANOVA, the F-value of the fiber percentages for compressive strength is 1.864, and it is lower than the F-critical value which is 3.009. This indicates that the said independent variable does not have a significant impact on the compressive strength of the samples. This is the opposite for the curing period because its F-value and F-critical value are 36.215 and 3.403, respectively. The interaction of the two independent variables has an F-value of 0.768 while its F-critical value is 2.508, indicating no significant difference. In the case of water absorption, both independent variables and their interaction impose a significant impact, with F- and F-critical values of 61.054 and 4.747 for the fiber percentage, 13.098 and 3.885 for the curing period, and 37.373 and 3.885 for their interaction. The statistical relationships between density and the other variables resemble those of compressive strength. The F-value of fiber percentage is 0.80, which is lower than its F-critical value of 3.009. The interaction of fiber percentage and curing period has F- and F-critical values of 1.25 and 2.508, respectively, indicating no significant impact. The curing period is the only variable significantly affecting density, with an F-value of 10.5.

Optimum Fiber Percentage

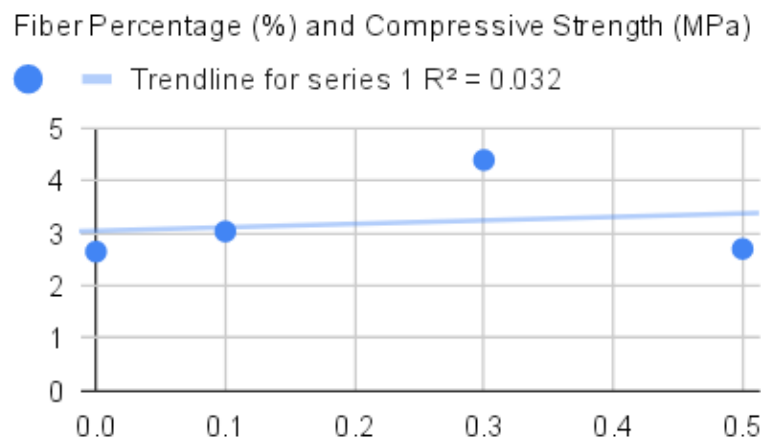


Figure 4. 7-day Curing Period Regression Analysis

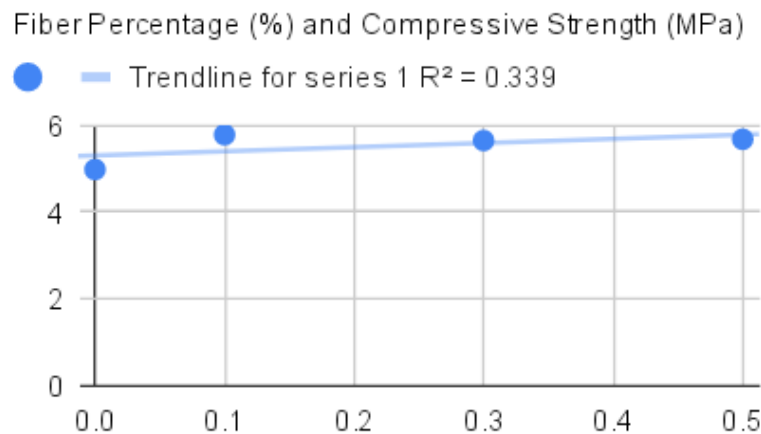


Figure 5. 14-day Curing Period Regression Analysis

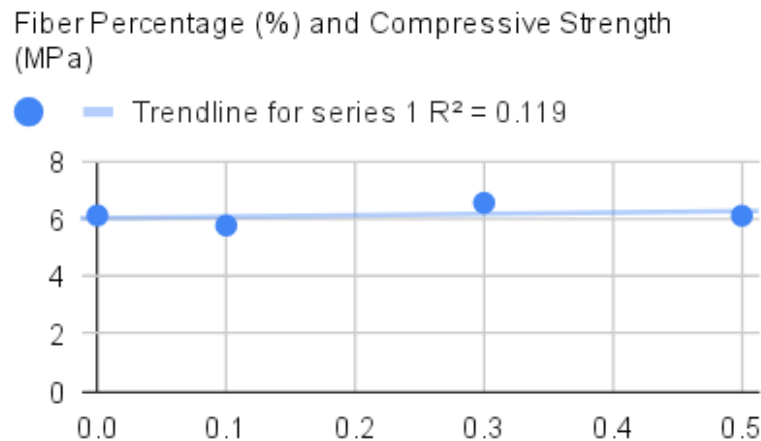


Figure 6. 28-day Curing Period Regression Analysis

Based on the composite performance evaluation, the 0.3% fiber content was identified as the optimum mix among the tested proportions. However, the ANOVA results indicate that the observed differences were not statistically significant; therefore, the identified optimum should be interpreted as a performance-based selection rather than a statistically confirmed superiority.

Production Cost

A typical 5-inch CHB with a cement-to-sand ratio of 1:7 is expected to sell for about ₱16.00 per piece. The calculation was done using a 5-inch CHB with a volume of 0.0068 m³. A dry volume factor of 1.54 was used to account for voids and compaction during mixing, resulting in a total dry material volume of 0.01 m³. The amount of cement and crushed sand needed per block, using the 1:7 mix proportion, is roughly 0.00131 m³ and 0.00916 m³, respectively. The anticipated cost of cement per block is ₱5.20 with a bag of cement equal to 0.028 m³, and the cost of sand is around ₱4.80.

Additional production expenses were also considered, including water (₱0.10), labor (₱2.00), machine use and molding (₱0.70), curing and handling (₱0.40), delivery (₱1.30), and a small supplier profit of about ₱1.50. Combining all these results in an estimated market price of ₱16.00 per CHB, which is consistent with typical low-cost CHB production in the Philippines due to mass production and standard 1:7 mixing ratios.

One sack of coconut husks, which costs ₱100 and contains ten husks, was used to determine the production cost of coconut fiber for CFRCHB. These provide roughly 1.5 kg of coconut fiber, or 600 g of usable fiber. As a result, the estimated cost of fiber per gram is ₱0.17. Given that each CHB needs roughly 4.53 grams of coconut fiber, the cost of coconut fiber per block is roughly ₱0.77, resulting in a total production cost of roughly ₱1.07 per piece. Therefore, under typical CHB manufacturing conditions, a CFRCHB is anticipated to cost around ₱17.07 per piece.

For a square meter of wall, each block requires 0.0051 m³ of mortar, totaling 0.0714 m³ per square meter, along with 0.8568 bags of cement and 0.0714 m³ of sand. Plastering adds 0.0032 m³ of cement (0.5376 bags) and 0.0448 m³ of sand. This results in total material costs of approximately ₱313.74 for cement and ₱116.20 for sand per square meter, excluding reinforcement. A 6-meter 12-mm Grade 40 rebar is projected to cost ₱210, and tie wire costs ₱90 per kilogram, making the total cost of reinforcing approximately ₱300.

In terms of overall production cost, about 12.5 CHBs are typically needed per square meter. The production cost for a square meter of standard 5-inch CHB is estimated at ₱929.94, while the CFRCHB version is slightly higher at ₱943.32. This represents an increase of about 1.44% in total production cost.

The increase is relatively small and acceptable because it comes from the added cost of incorporating coconut fiber into the mix. Even with this slight rise, the use of coconut fiber improves the block's strength, crack resistance, and overall durability. The improved performance and sustainability benefits help balance the additional cost, making the CFRCHB a practical alternative to the standard CHB.

Conclusion

The data showed that the incorporation of coconut fiber increased the compressive strength of the CHB, particularly at 0.3% fiber content, which consistently produced higher strength values than the control samples across the curing periods. The findings of the study confirmed that adding coconut fiber in the production of CHB affects its compressive strength at three different curing periods (7, 14, and 28 days), which supports the objective of determining the effect of coconut fiber reinforcement on compressive strength. However, despite the observed increase in compressive strength values, the analysis revealed that there was no significant difference between the control samples and the CFRCHB samples with 0.3% coconut fiber. This indicates that the improvement in compressive strength was primarily influenced by the curing period rather than the coconut fiber itself, since cement hydration remained the main factor contributing to strength development. Nevertheless, the results further indicate that coconut fiber-reinforced CHB can be considered conditionally stable, as the blocks maintained satisfactory compressive strength throughout the curing periods without showing a significant reduction in structural performance. With proper mix proportioning and curing practices, the CFRCHB with 0.3% coconut fiber may be suitable for non-load bearing and selected residential housing applications, particularly in low-rise residential structures where moderate strength and sustainability are preferred. In line with this, the optimum percentage of 6 cm coconut fiber based on the compressive strength results was used as the reference for the water absorption testing. It was observed that the control samples showed an increasing trend, while the 0.3% CFRCHB exhibited a varying trend. Still, the 0.3% CFRCHB produced a lower overall value. Achieving lower water absorption suggests reduced porosity and improved resistance to moisture penetration. For the water absorption test, the 0.3% CFRCHB obtained the lowest value at the 14-day and 28-day curing periods. Therefore, the incorporation of coconut fibers improves the durability of CHB, making it more dependable for long-term use.

In terms of density, the increase observed throughout the three curing periods indicates better compaction of the blocks. The control CHB and the 0.3% CFRCHB showed only a 0.7% difference in density at 28 days, which is consistent with the results of the one-way ANOVA. The incorporation of coconut fiber did not significantly affect the density, indicating that its effect can be considered negligible. This suggests that CFRCHBs remain structurally suitable and can still be effectively utilized in construction without compromising block quality.

The two-way analysis of variance showed that there is a significant difference in the compressive strength and density of the samples across different curing periods, while no significant difference was observed in the compressive strength and density of the specimens with varying fiber percentages and in the interaction between the two variables. For the absorption test, however, there was a significant difference in the values with varying curing periods, different fiber percentages, and the interaction between these variables.

The one-way analysis of variance also identified fiber percentage as statistically significant to the compressive strength of samples with the shortest curing period, while it was found insignificant for those cured over longer periods. In contrast, for water absorption, fiber percentage significantly affected the samples cured for longer periods, while it had no significant effect on those with the shortest curing time. Meanwhile, fiber percentage did not significantly influence the density of the specimens.

Across all curing periods, compressive strength reached its peak at 0.3% fiber content before decreasing or showing only minimal improvement at 0.5%. The regression analysis demonstrated that 0.3% fiber content provided the most balanced and efficient compressive strength performance, making it the optimum fiber content for the study.

The cost analysis showed that incorporating coconut fiber into CHBs resulted in only a minimal increase in overall construction cost. Due to the addition of fiber, the unit price of CFRCHB increased by ₱1.07, while the production cost per wall area increased by only 1.44% compared to conventional CHB. This relatively small increase indicates that CFRCHB remains a cost-efficient alternative, especially when considering its possible improvements in strength and performance. Therefore, the use of CFRCHB may be considered economically viable for construction applications, as the slight increase in cost can be justified by the added benefits it offers.

Based on the estimates conducted in this study, it can be inferred that the use of CFRCHB for a one-storey single-detached housing unit is a practical alternative to conventional CHB. The estimated production cost using CFRCHB was ₱229,590.86, which is lower than the estimated cost of ₱249,455.24 for conventional CHB. This represents approximately a 7.96% decrease in construction cost, indicating that the use of CFRCHB can significantly reduce overall expenses without compromising the structural integrity of the building. The findings suggest that CFRCHB is a cost-efficient material that is suitable for projects with limited budgets. In addition, the utilization of coconut fiber promotes sustainability through the use of locally available agricultural waste materials, making CFRCHB both an economical and environmentally sustainable option for future construction applications.

Any change in the material composition of CHB immediately affects the structural performance of the wall system as a whole because they serve as both partition elements and load-distributing wall components in many low-rise buildings. Walls in masonry construction are in charge of carrying loads down to the base from slabs, beams, roofing systems, and other structural elements. Lower-strength blocks may lessen the wall's capacity to safely withstand axial loads and stresses since the masonry unit's compressive strength greatly influences the wall assembly's overall strength. Therefore, unless further testing verifies compliance with structural design standards and building code requirements, the installation of CFRCHB should be restricted to low-rise residential buildings, non-critical load-bearing walls, or non-load-bearing partition walls. By serving as crack-bridging components inside the cement matrix, the addition of coconut fibers may increase crack resistance. These fibers can aid in limiting the spread of micro-cracks, by more equally spreading tensile stresses throughout the block. In real-world applications, this might lessen crack formation and modest shrinkage cracking in wall systems brought on by temperature changes, drying shrinkage, or little differential settlements. In terms of load transfer, the structural behavior of masonry walls is dependent on the efficient transmission of compressive forces through interconnected masonry units. The effectiveness of stress transfer within the wall system may also be lowered since CFRCHBs with larger fiber concentrations showed lower compressive strengths. These factors must be considered, because masonry units may undergo crushing or deformation, which could eventually cause unequal stress distribution and structural instability.

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References

- [1] Li S, Yang L. (2019). Analysis of the effect of substitution rate on the mechanical properties of recycled concrete hollow block. *Advances in Materials Science and Engineering*. 2019: 7546376. <https://doi.org/10.1155/2019/7546376>.
- [2] Kushwaha ER. (2023). The advantages and disadvantages of hollow bricks. *Civil Tutorials*. https://civiltutorials.com/hollow-bricks/#google_vignette.
- [3] Azevedo ARG, Filho FCG, Martinelli FRB, Marvila MT, Monteiro SN, Ribeiro FRC. (2023). A review of the use of coconut fiber in cement composites. *Polymers*. 15(5): 1309. <https://doi.org/10.3390/polym15051309>.
- [4] Bui H, Sebaibi N, Boutouil M, Levacher D. (2020). Determination and review of physical and mechanical properties of raw and treated coconut fibers for their recycling in construction materials. *Fibers*. 8(6): 37. <https://doi.org/10.3390/fib8060037>.
- [5] Izquierdo IS, Izquierdo OS, Ramalho MA, Taliencio A. (2017). Sisal fiber reinforced hollow concrete blocks for structural applications: testing and modeling. *Construction and Building Materials*. 151: 98–112.
- [6] NaturLoop – Philippines. (2022). REPIC. <https://www.repic.ch/en/revaloriser-les-dechets-de-coco-aux-philippines>.
- [7] Villar turns coconut wastes into a viable source of income, sustainable waste management initiative. (2020). *Manila Bulletin*. <https://mb.com.ph/2020/11/12/villar-turns-coconut-wastes-into-a-viable-source-of-income-sustainable-waste-management-initiative/>.
- [8] Ajwad A, Ali T, Anwar N, Kahla NB, Nawab MS, Qureshi MZ, Sun Y, Zaid O. (2023). A study on improving the performance of cement-based mortar with silica fume, metakaolin, and coconut fibers. *Case Studies in Construction Materials*. 19: e02480. <https://doi.org/10.1016/j.cscm.2023.e02480>.
- [9] Sanou I, Bamogo H, Sory N, Gansore A, Millogo Y. (2024). Effect of the coconut fibers and cement on the physico-mechanical and thermal properties of adobe blocks. *Heliyon*. 10(19): e38752.
- [10] Kazi S, Munde AR, Shingade VS, Shelar SV, Shelar VV. (2024). A study of the effect of coconut fiber on reinforced concrete beams subjected to combined bending and shear. *World Journal of Advanced Engineering Technology and Sciences*. 13(1): 556–568.
- [11] Baguhin I, Cabahug R. (2019). Investigation on load-bearing concrete hollow block reinforced with coconut coir fiber. *Mindanao Journal of Science and Technology*. 17: 153–166.
- [12] Dela Cruz JM, Dela Rea A, Magalong CA, Malay C, Poyaoan KA, Velarde CM. (2020). Coconut (*Cocos nucifera* L.) waste as partial coarse aggregate replacement for concrete hollow blocks. *Asia Pacific Journal of Multidisciplinary Research*. 8(3).

- [13] Ganiron T, Ucol-Ganiron N, Ganiron III T. (2017). Recycling of waste coconut shells as substitute for aggregates in mix proportioning of concrete hollow blocks. *The Scientific World Journal*. 77(2): 107–123.
- [14] Gatdula MM, Samson C. (2025). Utilization of coconut coir as an additional fiber reinforcement and partial replacement of sand in concrete hollow block. *International Journal of Research and Innovation in Applied Science*. 10(4): 470–478.
- [15] Rumbayan R, Sudarno, Ticoalu A. (2020). The development of coir-concrete blocks as lightweight construction material. *International Journal of Innovative Technology and Exploring Engineering*. 9(3).